Turbulent Economy or Key Indicators of Innovative Development

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Abstract

The paper presents an analysis of economic indicators characterizing the innovative development of industrial production and technology transfer. A statistical analysis of indicators of innovative development was conducted for the countries with the largest GDP volumes. The key indicators of innovative development that are essential for implementation of intensive technology transfer have been identified and justified. These include science funding, the amount of internal loans, and the metal-working machinery production. The conclusions drawn are based on an analysis of countries that demonstrated either accelerated or slow development as compared to the global average.

Keywords: innovation, technology transfer, economic development, internal loan, metal-working machinery production, statistical analysis.

Introduction

The relevance of the research topic is determined by a number of factors, including the increasing role of innovations in the economy of developed countries, the importance of achieving technological sovereignty of the state based on the creation and production of high-tech equipment and products, the rapid and intensive application of scientific and technical developments, the implementation of a completed commercialization process – from an idea to a release of a finished product, and the GDP growth due to market development and export of innovative products.

The purpose of this analysis is to ascertain and justify the necessary conditions and key indicators for innovative scientific and technological advancement.

Innovative indicators and indices

In the field of technology transfer, which encompasses the processes of obtaining, disseminating, and using novel knowledge, there are typically three key participants. These are, firstly, an organization (research institutes or universities) from whom the innovation is transferred; secondly, the organization (businesses or industrial enterprises) to whom it is transferred; and thirdly, business environment in which the transfer occurs. This model is known as the triple helix model (Patel & Pavitt, 1994). In the context of innovative economy, these subjects of the national innovation system converge in terms of the functions they perform, the goals they pursue, and the results of their activities (Wissema, 2009). Research institutes and universities are the source of innovations and the holders of intellectual property, which must be transferred to production phase. Businesses or industrial enterprises use the findings of scientific research and should implement innovations in the high-tech production, as well as create and acquire intellectual property rights.

The commercialization of scientific and technical outcomes from research institutes and universities is dependent upon the capacity and opportunity for industrial enterprises to utilize innovations, that is, the presence of a high level of innovative potential and the availability of financial resources. The role of the state is of great consequence in the financing of fundamental research, the provision of education, the creation of infrastructure, and the stimulation of high-tech production. In this context, the state's role is to guarantee the feasibility of both fundamental

research and applied work, including the financing of research and development (R&D) in state research organizations at the nascent stages of technology completion. Additionally, the state can foster favorable conditions for business activity through legislative and tax policy as well as administrative procedures (Etzkowitz, 2008).

There are numerous quantitative indicators that elucidate the interaction of innovative companies and their efficacy, which reflect a multitude of facets of this process. As outlined in the Oslo Manual (Oslo Manual, 2018, p. 15), there are two principal categories of scientific and technical indicators that are directly pertinent to the assessment of innovation: firstly, the resources that are allocated to R&D, and secondly, patent statistics, which refer to the patents granted for the invention.

The initial allocation of resources to R&D is comprised of state and business expenditures. This indicator is widely acknowledged as being of paramount importance by researchers (Aghion & Howitt, 1998). In the 2000s, the failure to achieve the desired economic outcomes globally was attributed to a dearth of investment in R&D (Crescenzi et al., 2007). The level of investment in R&D is typically expressed as a percentage of gross domestic product (GDP). This indicator of R&D intensity is used to express the relative "innovativeness" of the state and is considered to be the main condition for the production of knowledge.

On the other hand, while investments in R&D are undoubtedly a crucial aspect of innovative development, they cannot be the sole measure of such advancement (Heller & Porter, 1978). Theoretical studies and practical observations demonstrate that investments in R&D must be accompanied by additional technological, social, and institutional factors in order to achieve successful economic development (Dosi et al., 2006). Heller and Porter focus on export indicators and the relationship between export and economic growth given that rapid export growth accelerates the development of industry and science.

The export of high-tech products is of particular importance as a consequence and confirmation of the country's technological superiority in individual sectors of industry, science, and technology. The author of the present study provides evidence to support the assertion that there is a correlation between the proportion of patent applications and the growth of high-tech product exports (Perepechko, 2014).

Since 2002, the United Nations Industrial Development Organization (UNIDO) has been calculating a composite index of industrial competitiveness for countries worldwide. This index is based on a set of indicators that characterize:

- the capacity to produce and export manufactured goods, defined as the proportion of high- and medium-technology products in the manufacturing industry's exports;
- the intensity of industrialization and the quality of exports, as well as the country's influence in the global economy, measured by the share of manufactured exports in total exports (Gorodnikova et al., 2017).

The Global Innovation Index (GII), published by the World Intellectual Property Organization (WIPO), Cornell University, and INSEAD is a well-known and highly regarded benchmark for measuring innovation performance at the national level. The GII is an assessment of innovation performance in 141 countries based on 79 indicators. These indicators, which assess a range of factors including legislation, institutions, infrastructure, market and business conditions, human capital, and science provide a means of measuring innovation and are therefore an invaluable tool for improving innovation policy. The GIIs are comprehensive in scope, encompassing all countries. It was thus necessary to introduce new variables and to achieve a balance between variable quality and generality.

The most comprehensive set of competitiveness indicators for various countries of the world is presented in the Global Competitiveness Report, developed by the World Economic Forum. To illustrate, patent statistics serve as an indicator of innovation activity (Acs & Audretsch, 1989). The number of patents for inventions that protected abroad is included in the category of technological capital of the country (Fagerberg et al., 2011), and is employed, for example, to

facilitate a comparison of the technological capabilities and development of the USA and Europe, two world regions that are of comparable political significance.

In the context of aforementioned, two following questions must be addressed: what are the key indicators for the innovation economy and what are the conditions required for scientific and technological development, i.e., for technology transfer?

The concept of turbulence in economics

In economics, the physical concept of turbulence is used as a “property of macroeconomic dynamics” (Burlachkov, 2009).

The term is taken from fluid mechanics, defined in 1937 by Taylor and Karman as “disordered flow that occurs in fluid when it flows past impermeable surfaces or when adjacent flows of the same fluid follow each other or penetrate one into another” (Roy, 1937).

A characteristic of fluid flow in hydrodynamics is the dimensionless Reynolds number, which takes into account the properties of the fluid (density and viscosity), the linear scale of the system, and the flow velocity. The transition from a layered laminar flow to a turbulent flow, or a turbulent transition, occurs when the flow of liquid or gas in a pipe or on a plate becomes turbulent and mixed, for example, in a boundary layer on a plate. This transition is characterized by an increase in the Reynolds number for the flow in the boundary layer above a certain critical value. (Hinze, 1959). If the Reynolds number is less than the critical value, then any disturbances introduced into the flow will fade, the flow will remain laminar, that is, unmixed and layered. The introduction of a disturbing element such as step or edge into a flow with a Reynolds number below the critical value will result in the formation of a stationary small vortex.

It can be demonstrated that the vortex will separate only if the Reynolds number is greater than the critical value. This results in the introduction of disturbance into the main flow, which, in turn, causes the flow to become explosively turbulent. In a turbulent flow, the intensity of convective heat and mass transfer is greater. From an economic perspective, this phenomenon can be correlated with the transfer of innovations.

As with disturbances in a fluid flow, innovations in the economic system may either develop or fade. In recent history, Japan, South Korea, and China have demonstrated an economic miracle: rapid development of business activity, double-digit annual GDP growth, and entry into world markets with high technologies (Golovina & Levchenko, 2019; Mosebach, 2018). What were the initiating factors in these processes? What was the source and the trigger?

It would be of interest to ascertain whether a similar critical number exists in the economy, whereby innovations are stifled if the characteristics of the system are less than system's critical value, and flourish if this number is greater than the critical one.

Key indicators

Let us highlight the main indicators, the key ones, which characterize the subjects of the national innovation system, namely science, industry, and the state.

The relationship of indicators characterizing the innovation potential of the economy has been analyzed by Perepechko and Yagolnitser, based on data for 40 countries leading in terms of GDP according to the World Bank. A statistical analysis yielded two factors, one pertaining to science and the other to industry (Perepechko & Yagolnitser, 2021). The factor associated with industry, innovative industrial potential, includes the export of high-tech products, the number of applications for inventions from residents, and the metal-working machinery production. This factor is understood as a characteristic of industry (one of the subjects of the national innovation system) from the standpoint of business receptivity to innovations and the development of science-intensive production.

Another factor relates to science: it includes the number of applications for inventions abroad, science funding, and income from intellectual property. It is called "productive potential of

science". The funding of R&D activities is a necessary condition for the human resourcing and material support of R&D, obtaining of results, patents and innovations. Furthermore, this indicator, namely the ratio of R&D expenditure to GDP, is regarded as one of the most significant index (Aghion & Howitt 1998; Crescenzi et. al., 2007).

With regard to the factor of "innovative industrial potential," the volume of metal-working machinery production or metal-working machinery building serves as a significant indicator of industrial and high-tech development. Occupying only a few percent of the share of manufactured goods, metal-working machinery building is of fundamental importance for the development of all branches of industry (Perepechko, 2023). It provides the main production base, which includes production capacities, qualified personnel, and production culture (Arnold, 2001). The construction of metal-working machinery is a significant contributor to scientific and technical advancement in the modern world. It is a capital-intensive endeavor that necessitates the involvement of highly skilled labor, which is why it is predominantly concentrated in countries that have attained a high level of industrialization. The data on the construction of metal-working machinery is similarly reliable, given the existence of analytical reviews of companies engaged in this field. One such review is published annually by Gardner Business Media, Inc.

What indicators can be used to characterize nation state, that is, the institutional environment in which innovations are developed and in which science and entrepreneurship interact?

The domestic loan policy of the state seems to be a necessary condition for the enhancement of innovation processes. In (Munshi Naser Ibne Afzal, 2014), the ratings of the innovation efficiency of countries are calculated based on three main variables, namely the secondary education enrollment rate, the labor force (aged 15–65) as a percentage of the total population, and the domestic loan expansion of business as a percentage of GDP.

The importance of implementing business lending policies, including reducing interest rates to expand production and, as a consequence, economic growth, is noted by Panfilov V.S. and co-authors in (Panfilov et al., 2017) with simultaneous focusing on the importance of spare capacity in the economy: “It is also necessary to understand that in order to solve the above-mentioned problems, not only reduction in the interest rates and loan expansion are required, but also their implementation by means of special tools that will allow the use of available spare capacity.”

This paper analyzes the experience of countries, which have pursued a policy of reducing interest rates after crises, and the dynamics of key macro-financial indicators during such periods. It is confirmed that the implementation of a policy of reducing interest rates promotes the expansion of production and, as a consequence, economic growth, but only if there is spare capacity in the economy.

The role of loan in economic development is irrefutable; it constitutes a principal factor influencing economic growth and enhancing the well-being of citizens (Avis, 2019). The availability of funds for entrepreneurial activities is a primary driver of economic activity, including the production of goods. This, in turn, can facilitate the development of high-tech production, as evidenced by China's experience in the 1980s.

Therefore, the availability of financial opportunities for business activity or the amount of loans issued to the private sector can be accepted as a significant indicator characterizing the institutional economic environment.

To justify the choice of significant indicators, let us consider examples of countries that have demonstrated accelerated economic development or its slowdown in comparison with the global average. In the 20th century, such an “economic miracle” was demonstrated by post-war Europe, Japan, South Korea, and China. These countries had or created heavy industry (metal-working machinery production), imported and borrowed high technologies, developed domestic science and education, and provided enterprises with access to financial resources. Argentina provides an illustrative case of a relatively gradual development process.

In order to facilitate the economic recovery of European countries in the aftermath of World War II, on 5 June 1947, American Secretary of State George Marshall presented at Harvard

University a program devised by the President Truman administration (the Marshall Plan or European Recovery Program). The plan encompassed three principal objectives: the provision of direct financial assistance to European countries for the restoration of the devastated economy, the modernization of industry, and the development of Europe as a whole; the elimination of trade barriers, the fostering of trade and economic collaboration, and the establishment of a unified European market for the sale of American products; and the counteraction of the spread of Soviet and socialist influence in the countries of Western Europe.

The policy of providing financial assistance was designed to facilitate the restoration of the European economy and its solvency. In this case, political aspects played a secondary role, rather than being the primary cause. That is, providing financial assistance was the main goal of the program. The plan proved effective, with post-war Europe demonstrating a robust recovery and its leading states attaining the highest rankings among developed countries.

In post-war Japan in 1949–1950s, American banker Joseph Dodge developed a plan to stabilize the Japanese economy (the so-called "Dodge Line") through "shock therapy". To overcome inflation, a tough tax reform was implemented, which was based on the principle of a progressive income tax. Instead of providing financial assistance to industrialists, the government directed its resources towards supporting the banking sector. This resulted in the disbursement of loans by financial institutions to businesses. The provision of loans and access to finance was a favorable factor for the restoration and development of the economy[1]. By the time the occupation ended (April 1952), the country's economy was almost completely restored. The transfer of the Marshall Plan experience to Japan allowed effective reconstruction for outdated areas of industry. The industry underwent a significant transformation, shifting from sectors that relied heavily on manual labor, such as consumer goods industry and textiles, to capital-intensive ones, including heavy industry. Subsequently, there was a further shift towards science-intensive sectors.

At the same time, Japan took the path of the active import of foreign equipment and technology. In the period from 1950 to 1971, over 15 thousand patents and licenses were acquired (mostly in the USA). Instead of significant financial and time expenditures on research, the Japanese acquired the rights to the developed product and improved it. By the end of the 60s, Japan had created a virtually universal structure of industrial production using the latest technologies.

In South Korea in the 1950s, the main directions of the economic development strategy were investments in infrastructure and providing a state support to approximately 30 large private companies (chaebols), which served as the locomotives of the country's technological development (Lee et. al., 1991). The history of the South Korean economy clearly shows the features of the Japanese model, which demonstrated very high growth rates until the 1990s.

Common features of the economic development of both countries include an accelerated increase in the technological component in the final product through the import of technology and access of large corporations to state financial resources; maximizing the use of access to U.S. financing and technology to sustain high rates of economic growth (Agabekov & Levina, 2017).

The most striking example of achieving technological sovereignty is demonstrated by China. By the beginning of formation of a multi-structured economy (the 1980s), China was developing its own education system, establishing the student training abroad (especially in the USA and Japan), encouraging the import of technologies that allow the development of progressive sectors of the economy such as the production of software, advanced materials, the telecommunications industry, biotechnology, and healthcare. China, which is currently a space and nuclear authority, has a diversified economy that is heavily reliant on foreign investment. Concurrently, the structure of the Chinese economy is such that approximately 80% of all foreign investors are ethnic Chinese (huaqiao) residing abroad (Karelina, 2015).

It is also worth noting the rapid recovery of the Russian (USSR) economy after the 1917 revolution, the civil war, and the Great Patriotic War of 1941–1945, which was accompanied by

1 http://mybank.ua/articles/articleDetail.do?yaponskoe_ekonomicheskoe_chudo&objectId=13595

funding for science (up to 4% of GDP in 1980), as well as metal-working machinery production. However, in accordance with the prevailing social structure, private enterprise lending was absent.

Over the past two decades, India has shown accelerated GDP growth, which increased by more than seven times during the period from 2000 to 2022, and is currently the fifth largest economy in the world. Since taking independence in 1947, the Indian economy has developed according to the socialist model, but in the 1990s, reforms were implemented towards developing private entrepreneurship and attracting foreign investment, which resulted in increased lending to the private sector and growth in metal-working machinery manufacturing.

Argentina can serve as a counter-example. The work (Lyubimov et al., 2019) presents a comparative analysis of Argentina and South Korea in the 20th century. Argentina is frequently referenced in literature as a case study exemplifying markedly unsuccessful economic development. At the beginning of the 20th century, this country was among the top ten rich countries in the world, ahead of France, Germany, and Italy. However, by the end of the 20th century, Argentina had settled among the catching-up countries, losing its status as a rich economy. Some authors see the reasons for Argentina lagging behind in the insufficient development and financing of education and science. However, it is also worth noting the relatively low level of lending to private companies, which stands at approximately 10–15% of GDP, and the dearth of financing for entrepreneurial activities.

Whence, the accessibility of financial prospects for entrepreneurs, as reflected in the amount of loans extended to the private sector, can be regarded as the third pivotal indicator delineating the institutional economic environment.

Examples of the influence of key indicators on economic development

In order to substantiate the selection of countries as examples of accelerated economic development, a list of countries, ranked according to their GDP in 1996 and 2021, is provided in Table 1 according to the data sourced from the World Bank[2].

Table 1. Leading countries in terms of GDP (billion US dollars)

	Country/Year	1996	Country/Year	2021
1	USA	8073.1	USA	23,315.1
2	Japan	4923.4	**China**	17,734.1
3	Germany	2497.2	Japan	4,940.9
4	France	1605.7	Germany	4,260.0
5	Great Britain	1419.6	**India**	3,176.3
6	Italy	1312.4	Great Britain	3,131.4
7	**China**	863.7	France	2,957.9
8	Brazil	850.4	Italy	2,108.0
9	Spain	642.6	Canada	1,988.3
10	Canada	630.6	**South Korea**	1,811.0
11	**South Korea**	610.2	**Russia**	1,778.8
12	Netherlands	450.5	Brazil	1,609.0
13	Mexico	432.2	Australia	1,552.7
14	Australia	401.3	Spain	1,427.4
15	**India**	392.9	Mexico	1,272.8
16	**Russia**	391.7	Indonesia	1,186.5

2 https://data.worldbank.org/indicator

Over the past three decades, developed countries have retained their leading positions, with the United States, Japan, and Germany remaining at the forefront. However, the BRIC countries have made notable gains in various economic indicators. China has ascended to the second position globally, while India and Russia have also risen in the rankings.

To confirm the significance of the chosen indicators (science funding, metal-working machinery production, and domestic loan to the private sector), statistical studies were conducted. The relationship between the chosen key indicators and other innovation indices was investigated, using data from 40 countries with a GDP ranking in 2016. (Table 2).

Table2. The correlation coefficients of significant indicators with data on intellectual property and high-tech exports for the first 40 countries selected by highest GDP in 2016

	1	2	3	5	6	8	9	10	12	13	14	15	16
1	1.00												
2	0.91	1.00											
3	0.45	0.39	1.00										
4	0.87	0.96	0.17	1.00									
5	0.57	0.39	0.66	0.30	1.00								
6	0.89	0.96	0.17	0.99	0.33	1.00							
7	0.56	0.39	0.68	0.29	0.96	0.32	**1.00**						
8	0.65	0.67	0.79	0.54	0.71	0.50	**0.66**	**1.00**					
9	**0.60**	**0.60**	**0.86**	**0.44**	**0.71**	**0.41**	**0.66**	**0.98**	**1.00**				
10	**0.86**	**0.85**	**0.59**	**0.76**	**0.57**	**0.80**	**0.62**	**0.59**	**0.57**	**1.00**			
11	0.89	0.90	0.46	0.87	0.59	0.86	**0.56**	**0.78**	0.71	0.80	1.00		
12	0.64	0.70	0.80	0.54	0.57	0.51	**0.54**	**0.96**	0.97	0.59	0.74	1.00	
13	**0.60**	**0.63**	**0.79**	**0.48**	**0.66**	**0.45**	**0.61**	**0.99**	**0.99**	**0.53**	**0.73**	**0.98**	**1.00**

Nomenclature:

1 - high-tech exports, US dollars
2 - applications for inventions of residents in their country, pcs.
3 - applications for inventions of residents of the country abroad, pcs.
4 - applications for trademarks of residents in their country, pcs.
5 - applications for trademarks of residents abroad, pcs.
6 - applications for design inventions of residents in their country, pcs.
7 - applications for design inventions of residents abroad, pcs.
8 - GDP, US dollars
9 - science spending
10 - metal-working machinery production, million UD dollars, 2015
11 - metal-working machinery import, 2015
12 - issued patents on information technology, pcs.
13 - domestic loan, US dollars

The results presented in Table 2 confirm the relationship of key significant indicators with data on intellectual property, metal-working machinery import, and export of high-tech products. Furthermore, this result indicates that the current phase of economic development is occurring primarily due to the use of advanced technologies.

The factor analysis was conducted on the same countries (the first 40 countries by GDP in 2016) and indicators as presented in Table 1. The statistical software package SPSS was employed during the course of this analysis, employing the principal component method. The results corroborate the correlation between indicators such as the volume of exported high-tech goods, the number of applications for inventions, the amount of funding for scientific research, metal-working machinery production and import, and the number of issued patents on information technology.

This evidence points to the existence of a specific factor the so-called "economic Reynolds number" (Table 3).

Table 3. Main components of the identified specific factor

Indicator	Coefficient
High-tech export	0.82
Applications for inventions by residents in their own country	0.82
Applications for inventions by residents abroad	0.78
GDP	0.95
Expenses on scientific research	0.93
Metal-working machinery production, 2015	0.79
Metal-working machinery import, 2015	0.88
Issued patents on information technology in 2016	0.93
Domestic loan, USD	0.93

To justify the choice based on three significant indicators, the analysis was provided for the following countries: Germany, China, South Korea, Japan, USA, Russia, India, and Argentina.

Funding for scientific research as a share of GDP is presented in Table 4. In the United States, the growth of these expenses began after World War II, from 0.6% of GDP in 1940 to 2.9% in 1964 due to an increase in the weight of federal funds, whose share in the R&D expenditure increased from 21% in 1940 to 65% in 1964. For more than half a century, more than 2.5% of GDP has been spent on scientific research in the United States (exactly 2.5% in 1980, and 3.46% in 2021), while in accordance with the GDP growth, this money supply grows more significantly in absolute terms[3].

A comparable surge in scientific funding has been observed across all developed countries since the end of the 20th century. As evidenced in (Avdulov & Kulkin, 2011), the prevailing trends and patterns in the formation of a robust scientific and educational foundation – the cornerstone of contemporary socio-economic advancement – are now discernible. In 2021, the R&D expenditure in China was 2.4% of GDP, and in South Korea, according to the World Bank, it was 4.9% (Table 4). As for Russia, the R&D expenditure in 2021 was 1.09%, in India, it was 0.7%.

The R&D expenditure is incurred by the state and the private sector. The state R&D expenditure in all countries is less than 1% of GDP (Fig. 1), while private sector funding of scientific research (Fig. 2) in developed countries exceeds significantly the state expenditure on this activity.

[3] https://i-sng.ru/observer/observer/N16-17_94/16-17_18.htm

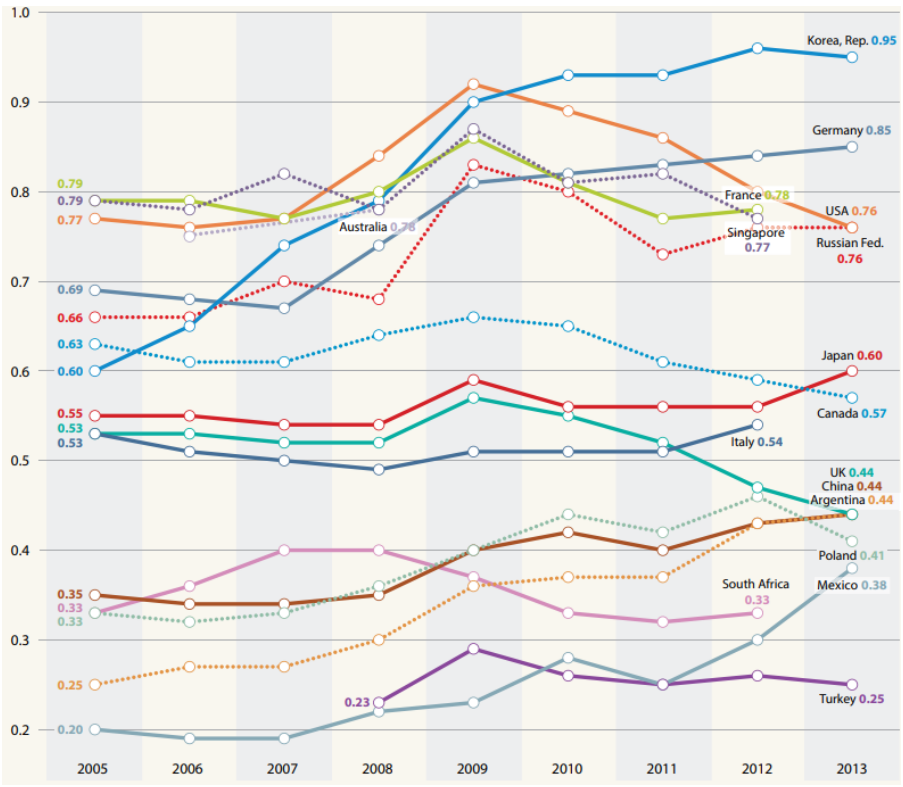

Figure 1 – State R&D expenditure (% of GDP); source: OECD's Main Science and Technology Indicators, September 2015.

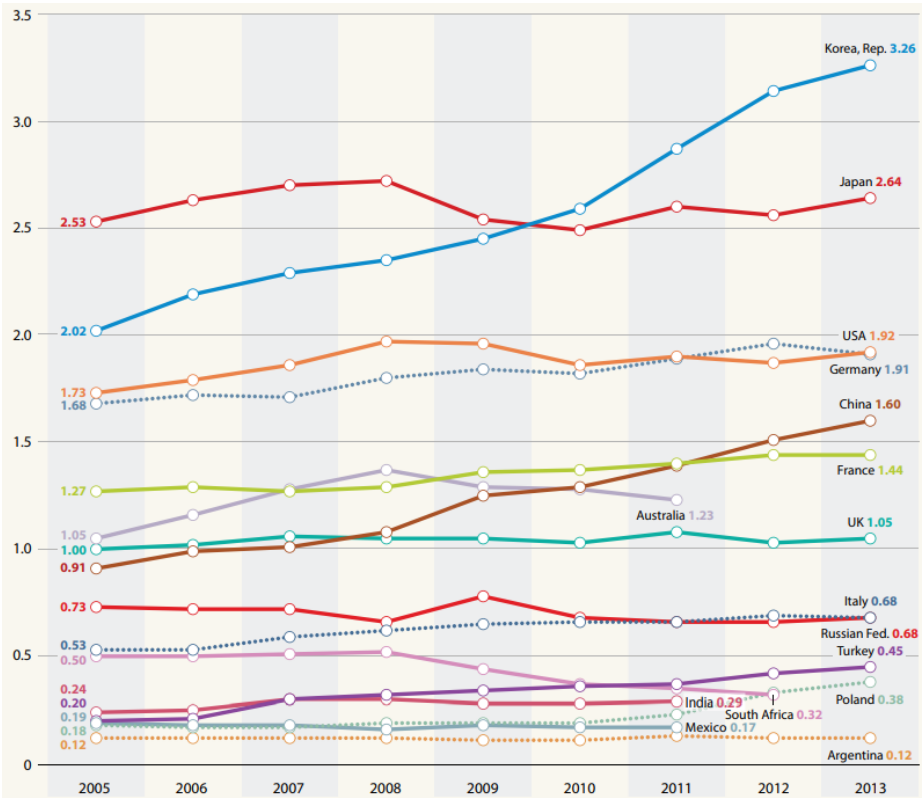

Figure 2 – Private sector R&D expenditures (% of GDP); source: OECD's Main Science and Technology Indicators, September 2015.

Table 4. Total funding for science as a share of GDP (%, S)

Country / Year	1996	2013	2017	2021
Germany	2.13	2.84	3.03	3.14
China	0.56	2.0	2.12	2.43
South Korea	2.3	3.95	4.6	4.93
Japan	2.7	3.28	3.2	3.3
USA	2.4	2.7	2.8	3.46
Russia	0.97	1.03	1.1	1.09 (2020)
India	0.64	0.7	0.7	0.7
Argentina	0.4	0.62	0.5	0.51

In terms of metal-working machinery production, Germany and the United States were the largest manufacturers before 1980, holding 20.9 and 18.3% of the world market, respectively (Table 5). Japan and the USSR also had shares of over 10%. Subsequently, the situation underwent a transformation over the course of the following years. China, Japan, South Korea, and India were engaged in efforts to enhance their production capabilities, whereas the United States was pursuing a reduction in such activities (Table 6). Russia is undertaking a process of industrial recovery, with a notable expansion in the production of metal-working machinery over the past five years. Argentina serves as an illustrative example of a nation that has fallen behind in this regard.

Table 5 — Metal-working machinery production in million US dollars

Country / Year	1980	1996	2013	2017	2021
Germany (FRG and GDR)	9,729	8,984.9	14,688	12,835.9	10,454.7
China	730	2,070.8	24,980	23,592.4	25,365.1
South Korea	235	1,441.1	5,306	4,814.1	4,424.4
Japan	6,656	10,916.3	12,326	12,480.4	10,351.2
USA	8,363	5,374.9	4,956	5,185.9	7,383.7
Russia (USSR)	5,327	223.1	211	560.9	701.2
India	282.7	270.6	658	1029	781.4
Argentina	37	28.1	43	79.3	74.4
Global	45,741.7	44,583.5	69,317.3	83,260.9	82,441.9

Table 6. The proportion of national metal-working machinery production of global metal-working machinery production

Country / Year	1980	1996	2013	2017	2021
Germany	21.3	20.2	21.2	15.4	12.7
China	1.6	4.6	36.0	28.3	30.8
South Korea	0.5	3.2	7.7	5.8	5.4
Japan	14.6	24.5	17.8	15.0	12.6
USA	18.3	12.1	7.2	6.2	9.0
Russia	11.7	0.5	0.3	0.7	0.9
India	0.6	0.6	0.95	1.2	0.95
Argentina	0.08	0.10	0.06	0.10	0.09
Global	100	100	100	100	100

The amount of internal loans as a percentage of GDP is shown in Table 7. Japan was the leader in this indicator in the 2000s, but at the beginning of the 21st century the United States came out ahead with more than 200% of GDP. It should be noted that the United States, Japan, China, and South Korea exhibit comparable dynamics, with domestic loan values ranging from 180 to 220% of GDP. Germany reduced internal lending from 110 to 80% of GDP. In Russia, this value is increasing, although it has not yet reached 55% of GDP. Argentina continues to be an exception to this trend.

Table 7. The proportion of domestic loans to GDP

Country / Year	1980	1996	2013	2017	2021
Germany	-	112 (2001)	82.2	77.6	84.5
China	52.6	89.5	134.3	154.9	178
South Korea	40.3	51.9	128.5	136.5	171.5
Japan	127	193.5	160.1	167.6	196.6
USA	94.3	137.7	184.6	191.6	216
Russia	-	16 (2001)	48	52.1	56.2
India	20.5	23.4	52	49	50
Argentina	25.4	20.2	15.7	15.96	15.9 (2017)
Global	-	121.5	118	126	145

Based on the above analysis, it can be assumed that the so-called “economic Reynolds number”, which plays a pivotal role in the advancement of high technologies, may be contigent upon three key factors: the R&D expenditure (S), metal-working machinery production (M), and the volume of domestic loans extended to the private sector (C):

$$Re_e = S \times M \times C \quad (1)$$

The values for the seven countries under consideration are provided in Table 8 for the years 2013, 2017, and 2021.

Table 8. Economic Reynolds numbers for 7 countries

Country / Year	1996	2013	2017	2021
Germany	4,818.9	4,946.7	3,624.8	3,364.7
China	230.6	9,679.6	9,305.0	13,308.1
South Korea	382.0	3885.3	3630.5	4537.5
Japan	12,800.0	9,337.8	8,039.2	8,145.9
USA	3,998.8	3,563.6	3,341.4	6,693.5
Russia	7.8	15.0	38.6	52.1
India	9.0	34.6	42.4	33.2
Argentina	0.8	0.6	0.8	0.7

Table 8 indicates that R&D expenditure, metal-working machinery production, and the amount of internal loans are the most significant indicators of innovative development, while their product (Re_e) for developed countries and China is greater than 3000.

In Russia, as the level of science funding is increased up to 2% of GDP, it is also necessary to facilitate an increase in the amount of internal loans to the private sector, as well as metal-working machinery production. This is a requisite condition for the successful transfer of technology and the attainment of technological sovereignty.

Conclusions

Based on the findings of the literature review and the results of the in-house research, the author suggests a set of three key economic indicators that are of pivotal importance for the innovative development of the state economy. These are: science financing, the amount of internal loans, and the production of metal-working machinery, which are prerequisites for the implementation of intensive technology transfer. A statistical analysis of 40 countries with the highest GDPs was conducted to determine the relationship between these indicators and data on intellectual property and the export of high-tech goods. The results are corroborated by the case studies of countries that exhibited accelerated or decelerated growth in comparison to the global average.

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Author Contribution

The author conceived and designed the study and collected the data, provided theoretical guidance and proposed revisions for the paper. The author has read and approved the final version of the paper.

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Data Availability

The data sets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations Competing Interests

The author declares no competing interest.

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